Experimental Study and Modeling of Two-phase Flow Cavitation and Flashing through Complex Valves

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Abstract

Two-phase flow are widely present in nuclear, chemical or mechanical engineering where different gas-liquid reactors, boilers, condensers, evaporators and/or combustion systems can be found. In these hydraulic systems the use of mechanical valves has a preponderant role for the security as it represents the ultimate protection before an accident. The complete understanding of the physics taking place in the flow through a valve becomes therefore crucial to guaranty this security of the protected process. In nuclear or thermal engineering systems the use of safety relief valves (SRV) is mandatory since it protects them against any over pressures. A careful design of the SRV is therefore essential. Reliable methods are available for SRV design in the cases of single phase flow such as liquid or gas discharge. When the static pressure through the valve falls below the liquid saturation pressure, vapor bubbles will form which tend to reduce the medium sound velocity. Similarly to compressible flow, this decrease of the speed of sound will be linked to limitation of the mass flow rate evacuated. In this two-phase flow, the single phase design methodology becomes inadequate. Currently, there are some calculation methods that attempt to predict the critical flow onset in SRV for two-phase systems knowing the inlet flow conditions and the outlet pressure; however none of them are acknowledged as being fully reliable as they make use of void fraction that is not currently measurable for flow experiencing cavitation.

This research project will be carried out at the von Karman Institute for Fluid Dynamics (VKI). A previous work carried out by Vasilis Kourakos focused on a two-phase flow through a SRV when air was injected upstream the valve. Several studies were performed and comparison with a transparent model was carried out at ambient temperature in an open loop. This previous work did not consider the case in which the fluid cavitates and/or flashes itself, being the reason why an external source of air was indeed needed to promote a two-phase flow.

The first part of the present research project is to update the VKI facility in order to increase the operational temperature and control the SRV back pressure. The new experimental facility will include a closed loop. Test conditions will be set through the control of a parallel pressurizing and vacuum system. Typically for water at 50C, cavitation will occur when the static pressure will fall below 12.3KPa.

Used measurement techniques will include; flow visualizations with a high-speed camera; unsteady pressure measurements upstream, inside and downstream the valve; temperature measurements; and void fraction measurement. This last technique will require a dedicated development. The proposed methodology consists in measuring the local sound velocity to retrieve the local void fraction. Proper calibration will have to be developed as well. Once knowing the void fraction in cavitation or flashing mode, the model predicting the mass flow rate such as the HNE-DS (2004) will be validated for the first time in this configuration.

Keywords: Two-phase flow, cavitation, flashing, safety relief valve, discharge coefficient